

# GIS Data within a Seamlessly Integrated 3D Environment

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## Abstract

For decades, users of GIS technologies have been investing in the compilation, maintenance, and deployment of GIS databases. Today's GIS databases tend to be extremely large and robust, accurately reflecting historical changes and the plethora of assets within the real world. These databases have typically been collected and stored using both 2D and 2.5D features, and, as a result, they do not lend themselves well to display within a 3D environment.

With 3D becoming a commonly used method of geospatial processing, there is a growing need for a system that unites a corporation's GIS data and 3D visualization. Specifically, a system is needed that someone with little to no training can use to connect to a wide variety of GIS databases and to rapidly visualize and interact with them in a 3D environment.

During this presentation, we will explore how GeoMedia can be used in tandem with GeoMedia 3D to meet this need. Specifically, we will investigate how GeoMedia technologies can be used to connect quickly to a collection of disparate GIS databases and to easily render their data inside a 3D environment as realistic representations and thematic 3D maps.

Realistic representations of our world are important because they can provide situational awareness; however, additional power lies in coupling the realistic representations of the world with a robust collection of thematic 3D mapping capabilities.

Thematic 3D maps augment our understanding of spatial phenomena because they distil complex spatial phenomena into simple, easy-to-interpret representations. More specifically, 3D thematic maps allow the user to better understand relationships within seemingly unconnected/unrelated data. Therefore, 3D thematic maps can be used to facilitate the decision-making process and to lead to quicker and more confident decisions.

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## Representing GIS Data in 3D

GeoMedia accesses data through connections, which are the conduits between GeoMedia and a warehouse. Warehouses are databases that contain GIS feature data, which consist of points, lines, areas, and images. Points can represent features such as fire hydrants, lines can represent features such as sewers, areas can represent features such as buildings, and images can represent information such as land-use. These GIS data sources can all be easily stylized to quickly create faithful renditions of the world in which we live.

### ***Stylizing Point Features***

Point features are geographic entities that can be described using a single location. These data are referred to as point feature classes and, as such, have a number of styles that apply to them. With the addition of 3D, these styles have been extended to take advantage of the third dimension. Users can, for example, use GeoMedia 3D to replace traditional 2D symbols with 3D symbols and, in turn, to use location and attribution to create realistic views of traditional GIS data.

In the example found in Figure 1 below, 3D symbols are used to represent the location of street furniture assets (such as traffic lights, street lights, palm trees, and fire hydrants) and the location of motor vehicles.



*Figure 1: A 3D map where 3D symbols are used in place of 2D symbols.*

Replacing 2D symbols with 3D symbols is important; however, making use of attribution is equally important to the process of rendering points features in a 3D environment. Attribute-based symbology is an integral part of GeoMedia. Attribute-based symbology allows users to control display characteristics via attribution, thereby allowing the creation of maps that convey a message or theme. For example, with GeoMedia 3D, users can create a map that reflects the relative pressure of each fire hydrant in a city using 3D point symbols. Specifically, users can create a graduated 3D symbol map where the size of each 3D fire hydrant symbol reflects the pressure value that is attached to each fire hydrant.

In the example found in Figure 2 below, 3D symbols are used to represent the location and relative pressure of each fire hydrant.



Figure 2: An example of how the size of each symbol can reflect the relative pressure.

GeoMedia supports notification and therefore changes to the underlying data dynamically percolate through to the map allowing users to view information that is current. Dynamic maps are an important part of situational-awareness applications and can play a fundamental role in the decision-making process.

An important concept to understand is that Z values, attribution, or user-defined values can be used to suspend point symbols above the surface, or even to attach a device on the side of another symbol or 3D object.

In the examples found in Figure 3 below, a 3D representation of a Pan, Tilt, Zoom (PTZ) camera is hovered a specific distance above the surface relative to another 3D model of a traffic light. With this approach, the PTZ camera appears to be connected to the traffic light, but in actuality, two features are used to represent these elements, and the two features can therefore be stylized independently of one another.

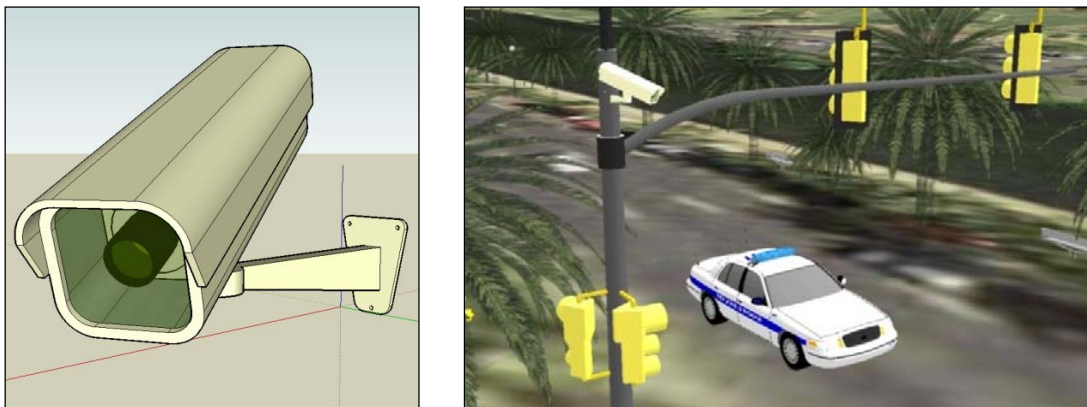


Figure 3: An example of PTZ camera suspended above surface near the traffic light.

## Stylizing Linear Features

Linear features are used to represent entities such as street centre lines, pipes, sewers, or power lines. With GeoMedia 3D, users can make use of the X, Y, Z, and attribution, and, as such, users can suspend linear features above the surface and/or display linear features that run parallel, relative, or vertically. This flexibility can also be useful for creating interesting thematic maps.

In Figure 4 below, Z values and attribution are used in tandem to create a thematic map of display linear features. The example on the left thematically maps telephone lines by type, while the map example on the right illustrates the use of Z values to represent pipes that include both horizontal and vertical runs.

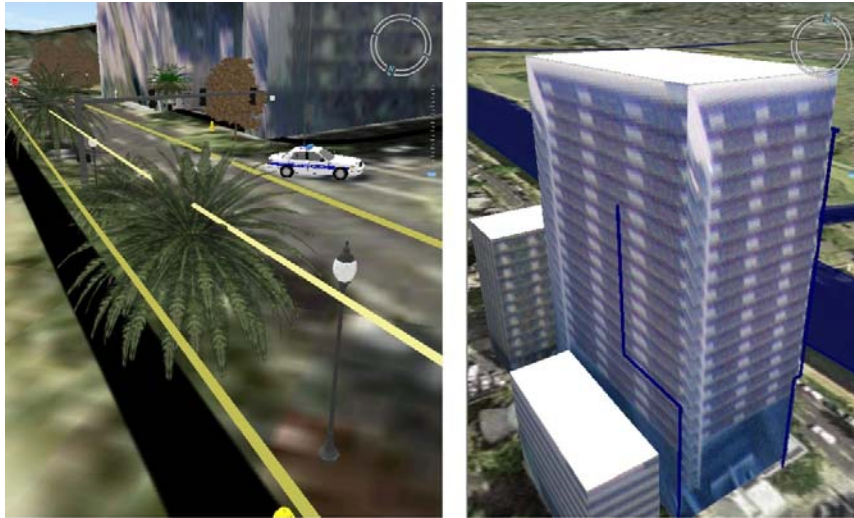


Figure 4: Example of 3D maps of linear features.

It is important to understand, however, that GeoMedia 3D is not designed for creating complex 3D objects; it is designed for enabling connectivity to your GIS data.

### ***Stylizing Area Features***

Area features are used to represent entities such as buildings, city parcels, or police beats. As illustrated in Figure 5 below, with GeoMedia 3D, property styles such as extrusion, side texture, and top texture can be used to create 3D representations of building footprints and thereby to provide some realism to 3D renderings.



Figure 5: Example of using texture files to texture the sides and tops of three buildings.

The addition of 3D not only allows users to create Level of Detail (LOD) 1 renditions of buildings, but with GeoMedia 3D users have access to their GIS data, including any attribution within a 3D environment. With GeoMedia 3D, users can extruded areas to reflect the magnitude of an attribute value. The concept of area-based 3D thematic maps is further explored below in the section entitled “Hotspot Detection: A Case Study in Thematic Mapping.”

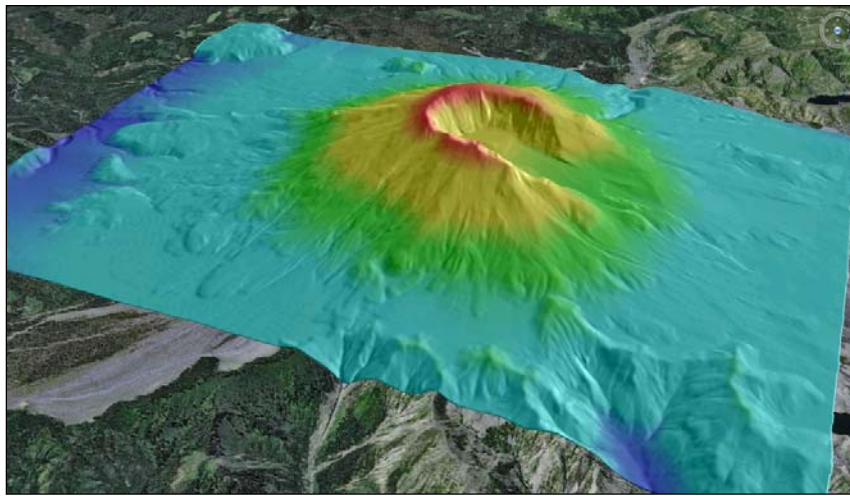


## ***Stylizing Image Features***

Imagery is an essential component of both 2D and 3D maps because imagery provides a realistic backdrop to geospatial data sets. It is important to note that imagery can be ordered in GeoMedia (that is, it can be layered one image on top of another). Layering is critical because it allows users to create a continuous fabric of imagery even when lower and higher resolutions of imagery are used.

Adding imagery to the 3D map window is no different than adding imagery to a 2D map window; GeoMedia 3D honours the Insert Image commands and image display properties and, as such, can be used to layer imagery and create composite views.

In Figure 6 below, high-resolution imagery was used in combination with a colour-coded DEM and a shaded-relief model to create a colour-coded, shaded-relief model. Note: This model was created using the Grid commands (Shaded Relief, Blending, and View Legend) and the Style Property commands within GeoMedia Advance.



*Figure 6: A colour-coded, shaded-relief model displayed in the context of aerial photographs using GeoMedia 3D.*

## 3D Models

GeoMedia 3D can use 3D models to further enhance the representation of the GIS data. Specifically, GeoMedia 3D supports the import, placement, and display of SKP, KMZ, COLLADA (DAE), CityGML, DirectX, and XPL objects. Users can add 3D objects via styles/properties dialog boxes in GeoMedia 3D, or they can import 3D objects via a utility specifically designed to convert a collection of 3D objects into a format that is optimized for GeoMedia 3D.



Figure 7: Buildings models (those with textures) imported via the Import 3D Objects utility.

The 3D environment depicted above in Figure 7 was created using a combination of GIS databases/features with a collection of imported 3D models. This functionality also allows thematic mapping to be displayed in the context of assets in the field. For example, as illustrated in Figure 8 below, incidents were aggregated by census tract and displayed in the context of a realistic city-scape.



Figure 8: Thematic mapping results displayed in the context of a realistic city-scape.

## 3D Thematic Mapping

Thematic, or choropleth, maps are maps specifically designed to depict a subject that is connected with a specific area (polygon feature), line (linear feature), or location (point feature). Thematic maps can effectively emphasize the spatial variation of geographic distributions. Distributions can be physical phenomena, such as temperature, or human characteristics, such as population. The main intent behind choropleth mapping is to discover spatial patterns and to present these findings as an easy-to-interpret picture.

3D thematic maps are, in simple terms, a natural evolution of traditional thematic maps. 3D thematic maps make use of volumetric symbols such as spheres, cubes, and surfaces to represent a value of a subject. 3D thematic mapping is not a new paradigm; however, with the rich and diverse GIS datasets readily available via connections, web services, and mash-ups alike, users now have easy access to all of their GIS and public GIS data, including attributions.

With GeoMedia 3D, users can take advantage of the connectivity within GeoMedia and can use the third dimension to create a rich collection of thematic maps. In short, 3D thematic maps, if designed correctly, can do the following:

- Augment our understanding of spatial phenomena because they distil complex spatial phenomena into easy-to-interpret representations
- Allow map readers to better understand relationships within seemingly unconnected/unrelated data
- Be used to facilitate the decision-making process and to lead to quicker and more confident decisions

Of all the different methods of mapping, 3D thematic mapping has benefited the most from the computerization of maps. The shading or tinting of areas of volumetric elements to depict attribute values is now becoming a common way to map a wide variety of geospatial data.

## Hotspot Detection: A Case Study in Thematic Mapping

### ***Hotspot Detection***

Hotspot detection is an approach that is ideally suited for extracting geographic concentrations, or hotspots, from sparse data sets. For example, this technique can be used to locate hotspots within data sets that contain Epidemiological (pandemic events), Law Enforcement (crime events and response times), Utilities (outage events), or Transportation (accident events and traffic flow) information..

In Figure 9 below, the Hotspot Detection command in Incident Analyst was used to identify areas containing a large volume of 911 calls for a specific week. This map was, in turn, used by authorities to implement a directed patrol protocol; in essence, the protocol was designed to proactively direct field officers where they were most needed given specific time slices.

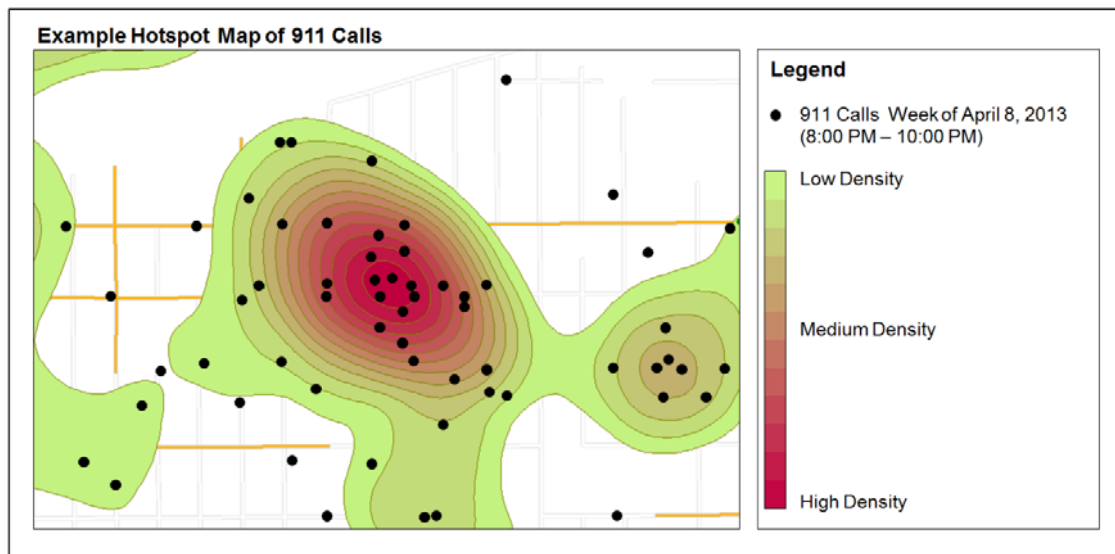


Figure 9: An example of a hotspot map using 911 emergency calls as input.

### ***Application Areas***

Hotspot detection simplifies complex spatial-point patterns by creating a surface of density values in which the density at each location reflects the concentration of points in the surrounding area. With this representation, analysts are able to see how incident densities vary within a geographic area. Hotspot mapping can therefore be used to address a number of challenges that many organizations struggle with. For example, hotspot mapping approaches can be used to do the following:

- Ascertain priority areas and the conditions experienced within them
- Locate where tactics have been deployed and to visualize their impact
- Discover areas at risk to a specific type of incident
- Identify emerging hot areas and predict where the problems may arise

Hotspots can also be used to analyse change over time. For example, multiple layers of car-crash densities can be used as input into correlation analysis or time-series analysis. The correlation analysis can be performed either by comparing two or more consecutive time periods (for example, one week to the next) or by comparing one time period to a similar one (for example, July of the current year to July of the previous year).



## 2D Thematic Mapping

In this portion of the case study, incident data was used in tandem with a collection of aerial photographs to create a collection of sample outputs. The product used to create the output was GeoMedia. The intent of this section is to illustrate how 2D thematic maps can be used to depict patterns within point data.

### Creating a Density Surface

GeoMedia was used to make a number of connections to a collection of data sources. Once these connections had been established, a simple base map of incident locations was created. Note: Graduated representations of stars were used to depict the number of incidents at each location. Namely, the point symbols increase in size as the number of occurrences at each location increase.

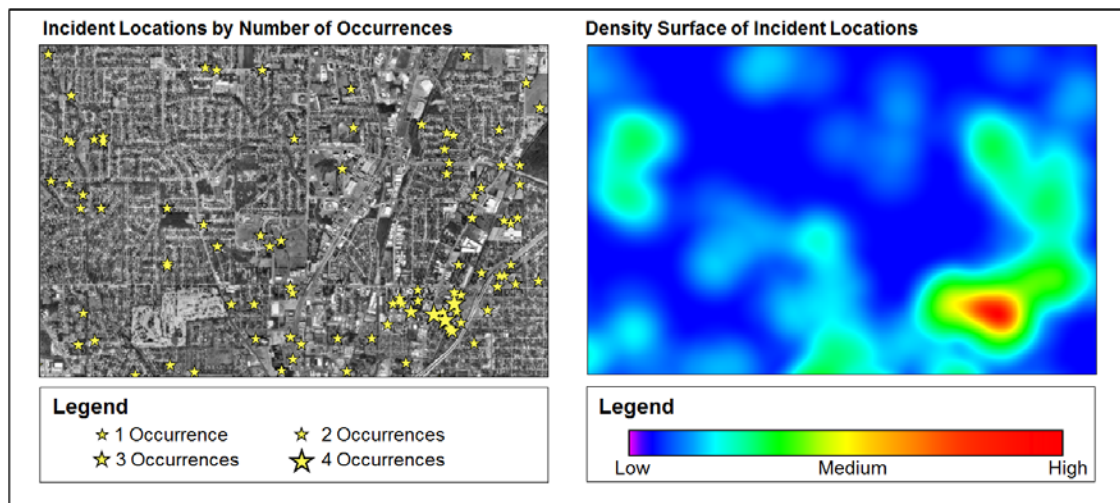


Figure 10: Number of occurrences at each incident location displayed as a density surface.

As depicted in Figure 10 above, the incident-location feature class can be used to create a density surface using the Grid > Surface > Density command.

The Density command is an interpolation function that uses kernel-density estimation to generate density maps. Kernel-density estimation is a way of estimating probability density functions of a random variable. Specifically, it can extract areas where the concentration of incidents is high, and it can identify clusters in geographic space, thereby distilling complex information into a simple picture. The output can be further synthesized (for example, used as input into the Isoline command to produce Isoline maps and/or used as input into the Group command to produce Thematic Hotspot maps).

Continuous-surface maps such as those created by the Density command use a variety of kernel shapes to aggregate points within a specified search radius (or bandwidth) to create a statistical surface that represents the density of events across an area. Kernel-density estimation is particularly useful for identifying the locations, the spatial extents, and the intensity of hotspots (that is, areas of high density) within a sparse matrix of incident locations.

The output of the Density command is a visually attractive surface and helps to invoke further investigation and exploration of the reasoning behind why incidents are concentrated in some areas. The resulting values of the density map are expressed as units of density.

A "density" unit is an amount of something per unit area. Population, for example, is defined only at the sampling unit level (household, block, census tract, county, state, or other region) but is frequently reported as a density, for example, people per square mile, per square kilometer.

The density is well-defined at all points, provided that the user specifies what region around a point is used to summarize the data. The population per square mile at any point could be computed by summing all discrete population values within a circle of radius  $\sqrt{1/\pi}$  miles. It could also be computed by summing

all discrete population values within a circle of radius of 100 miles and dividing by the circle's area ( $10,000 * \pi$  square miles).

As depicted in Figure 11 below, a density surface can be stylized within GeoMedia to display the density surface in the context of other feature classes.

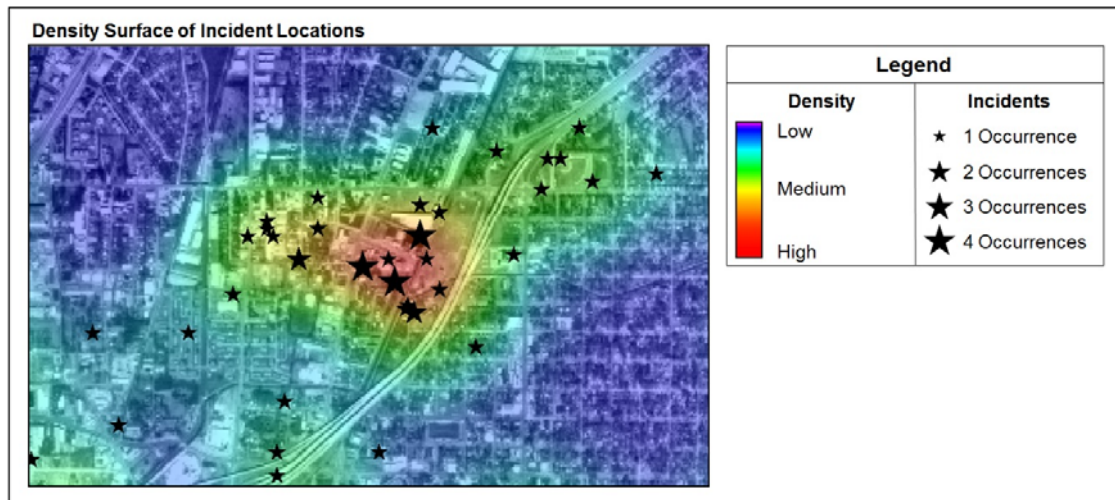


Figure 11: Density surface stylized to display in the context of base data and incident locations.

As shown in Figure 12 below, the Grid > Surface > Isolines command could be run using the density surface as input to better delineate discrete zones within the density surface. The Isolines command analyses a grid source layer of continuous data and returns a linear feature class of major and minor isolines. An isoline is a line or curve on a surface that connects points of equal data value.

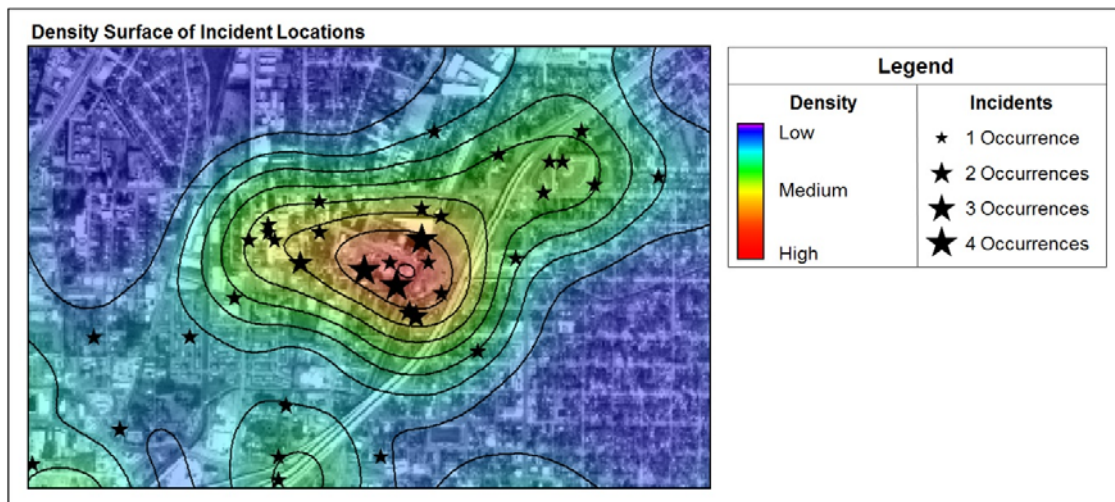


Figure 12: Isolines in the context of stylized density surface and incident locations (commonly referred to as isopleth maps).

## Extracting Hotspots

A hotspot is a centre of high activity within a larger area of low activity. Hotspot maps contain features (hotspots) that are used to generalize and simplify isopleth maps, which are maps that generalize and simplify data with a continuous distribution (that is, they show data as a third dimension on a map). Thus, isopleth maps are typically used to map data such as surface elevations, density values, amounts of precipitation, and atmospheric pressure. These maps can be created from a sparse matrix using an interpolation process such as Kriging, Inverse Distance Weighting (IDW), Spline, or Density Interpolation.

GeoMedia Grid includes a process for extracting hotspots from isopleth maps. The resultant hotspot maps are extremely useful for distilling complex information into a simple picture that almost any map reader/analyst can understand. These maps are therefore effective intelligence resources for public education. The map presented in Figure 13 below was created using the Grid > Classification > Hotspot Detection command.

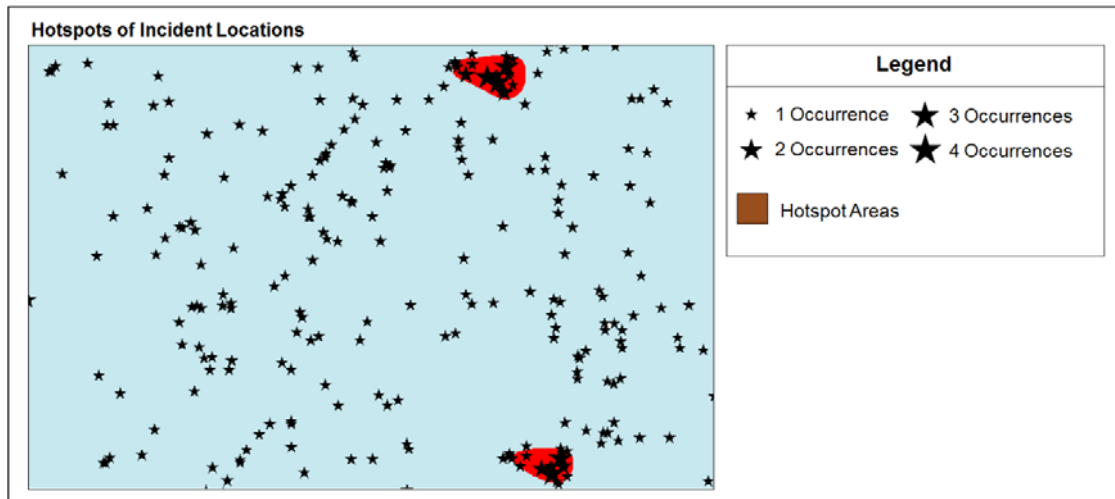


Figure 13: Incident locations in the context of hotspot areas.

The Hotspot Detection command includes a number of options to help determine a threshold value. The threshold value is used as a cut-off point. Specifically, any cell with a value greater than or equal to the threshold value is extracted and written to the output layer.

Note: All of the outputs produced thus far have been displayed using a traditional 2D map. In the next few sections, 3D approaches will be used to visualize this data.

### 3D Thematic Mapping

This section of the paper builds upon the datasets and results used in the section above. The products used here were GeoMedia and GeoMedia 3D. The intent of this section is to illustrate how 3D thematic maps can be used to visualize patterns within point data.

#### Creating a Graduated Pin Map

As discussed above, graduated representations of stars were used to depict the number of incidents at each location. These types of thematic maps are often called “repeat-incident” maps. Repeat-incident maps allow users to display locations where incidents occur more than once. These maps use symbol size and color to identify the recurrence of incidents in the same location. The benefits of these maps are that they do the following:

- Effectively portray repeat and non-repeat places on the same map
- Allow the map reader to quickly make comparisons among repeat places and the number of incidents
- Depict concentrations of hot places (or areas that contain several occurrences)

In basic terms, repeat incidents indicate a type of pattern. By most definitions, repeat incidents occur when the same type of incident is experienced by the same – or virtually the same – location within a specific period of time, such as a year. Repeat incidents refer to the total number of incidents experienced by a location, including the initial and subsequent incidents (for example, a person's house may have been burglarized twice in a year or 10 times in a year, and both examples are considered repeats.).



With GeoMedia 3D, three-dimensional symbols can be used to create these maps. In Figure 14 below, GeoMedia 3D was used to create a repeat-incident map (using graduated three dimensional pins) that was then combined with both the aerial photograph and density surface.

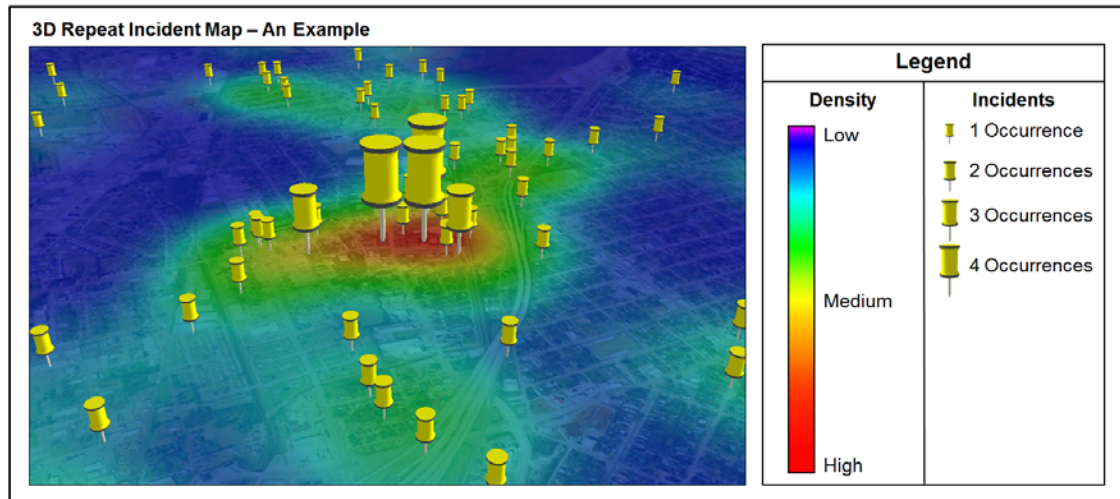


Figure 14: Density surface stylized to display in the context of base data and incident locations.

### Visualizing a Density Surface

As noted above, the Density command creates a visually attractive surface and helps to invoke further investigation and exploration of the reasoning behind why incidents are concentrated in some areas. The resulting values of the density map are expressed as units of density, however these values can be modified and expressed in linear units and in turn used within GeoMedia 3D as a surface.

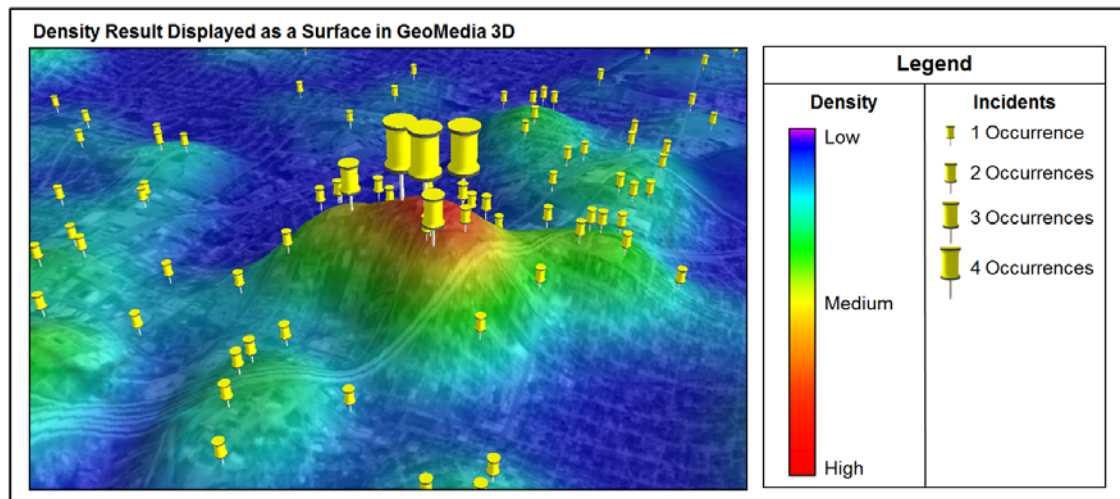


Figure 15: Density surface stylized to display as a surface in the context of base data and incident locations.

### Creating a Thematic Boundary Map

Boundary maps are maps of thematic displays of polygons that count the incidents that fall within it. These maps use colour to represent different values among land units, such as police precincts, city voting districts, or census tracts. They can be expressed as simple counts (for example, the number of incidents in a defined boundary) or as density values (for example, the number of incidents per square mile).

As can be seen in Figure 16 below, thematic boundary maps offer map users a broader perspective of where incidents occur without having to interpret a large number of individual locations.



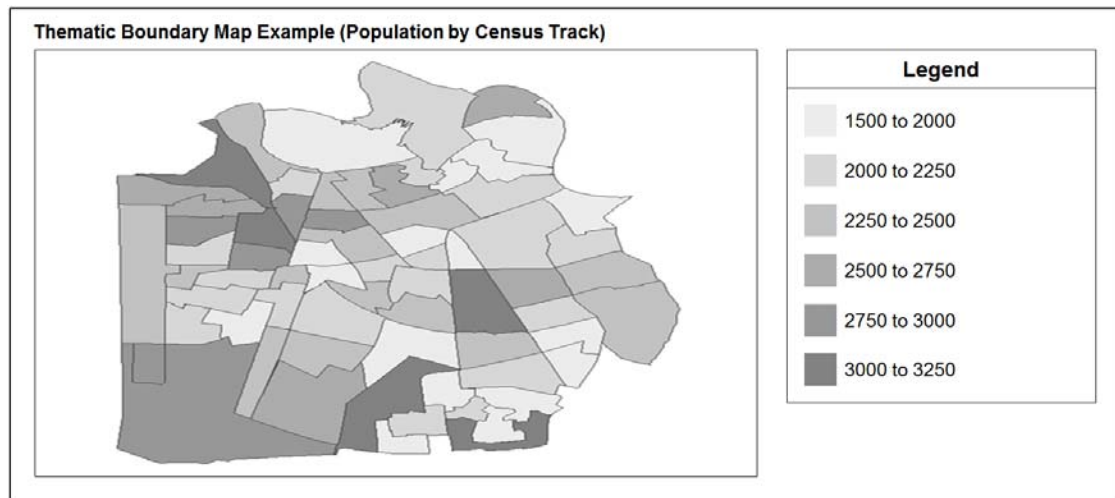


Figure 16: An example of a thematic/choropleth map.

Thematic boundary mapping is a popular technique for representing any spatial distribution as geographic-boundary thematic mapping. These geographic boundaries usually are defined as administrative or political areas such as beats, census blocks, polling districts, wards, or borough boundaries.

Incident events mapped as points can be aggregated to these geographic region or areas. These counts of events by their geographic areas can then be thematically mapped to display the spatial pattern of incidents across jurisdictions.

Grid-boundary maps are similar to thematic boundary maps; however, grid-boundary maps make use of polygons of equal size to aggregate the data. These polygons are typically square and range in size from 200 metres by 200 metres to 4 kilometres by 4 kilometres. The size depends on the area being analysed. Smaller areas are typically used in urban areas.

The map presented in Figure 17 below was created using GeoMedia. Namely, the Analysis > Analytical > Aggregation command was used in tandem with a functional attribute to calculate the total number of incidents that fell spatially within each of the grid-cell polygons. The results of this process were then displayed thematically using the total count value for each area.

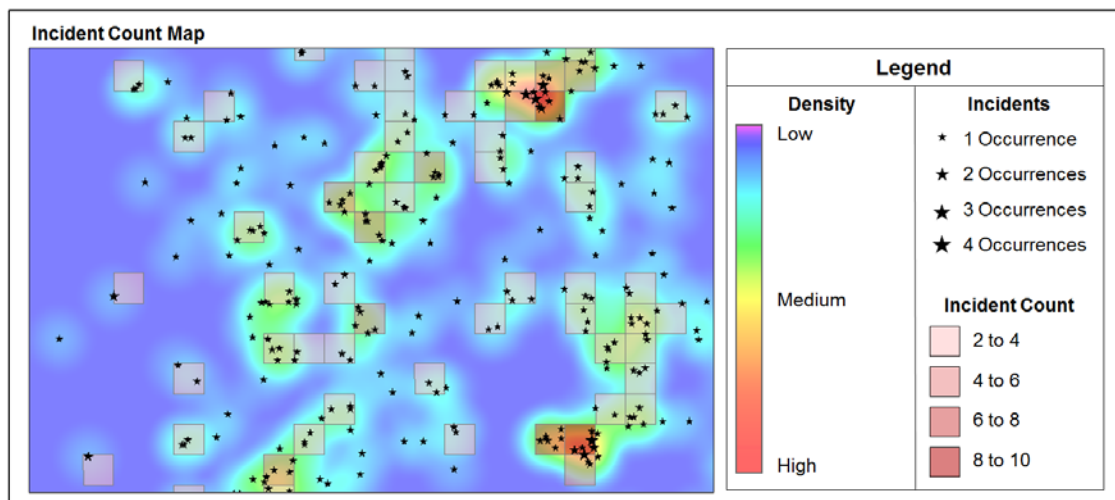


Figure 17: Incident counts in the context of density surface and incident locations.

With GeoMedia 3D, areas such as the incident gridded areas in the map presented above can be extruded to represent an attribute value. In Figure 18 below, GeoMedia 3D was used to create a 3D environment that effectively displays the thematic grid boundaries, repeat incidents, aerial photograph, and density surface.

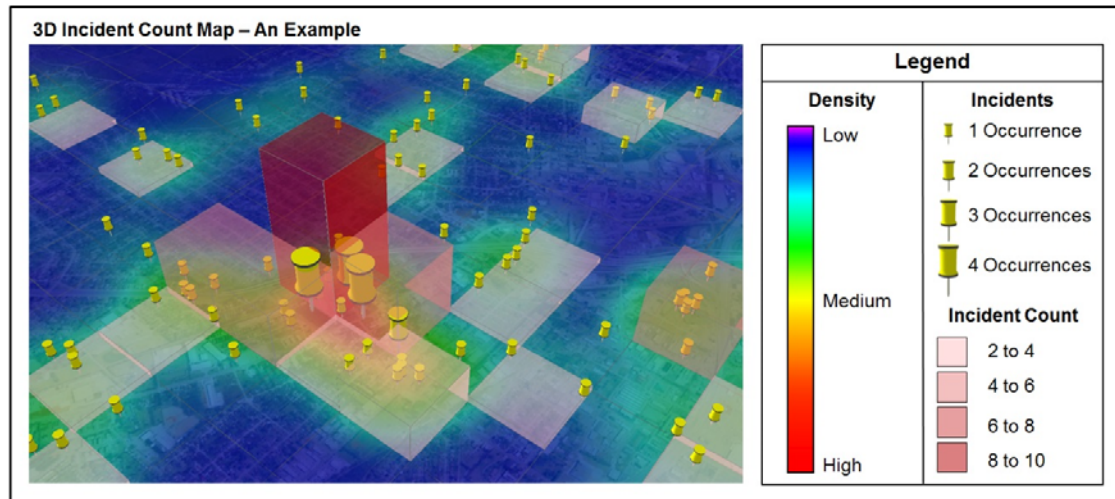


Figure 18: Incident counts in the context of density surface and incident locations.

Incident-count labels were added to each gridded area and displayed using a bill-boarding approach. These types of labels can be easily read no matter what the viewing angle is.

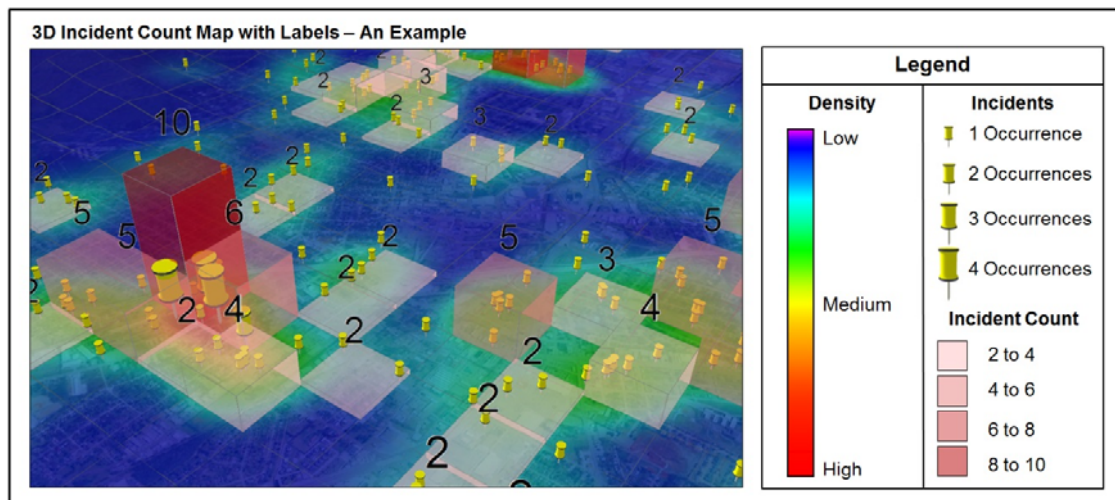
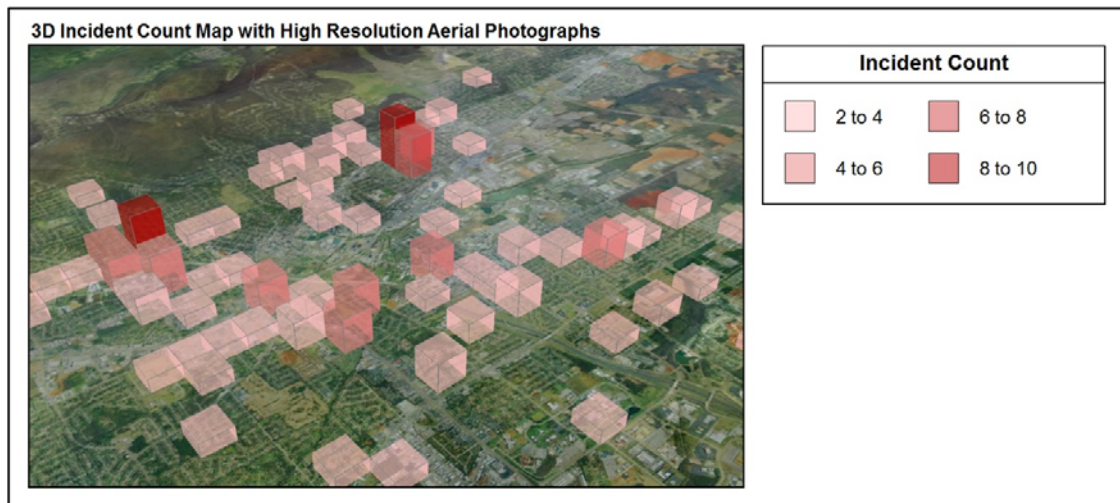


Figure 19: Incident counts and label counts in the context of density surface and incident locations.

Since users have fully control over all the features that make up the 3D environment maps can be modifies to display any combination of data sources and thereby allow users to get the representation that best suites specific needs. In the example provided below, high resolution aerial photographs were added and used in tandem with incident count results. With this map user can effectively see where the concentration of incidents are within an area.



*Figure 20: High resolution aerial photographs displayed in tandem with incident count results.*

## Summary

Realistic representations of our world are important because they provide put data into context and improve therefore improve situational awareness; however, additional power lies in coupling these realistic representations with a collection of thematic 3D mapping capabilities.

As demonstrated in this paper, thematic 3D maps augment our understanding of spatial phenomena because they distil complex spatial phenomena into simple, easy-to-interpret representations. More specifically, 3D thematic maps allow better understanding of the relationships within seemingly unconnected or unrelated data.

3D mapping in GIS is not new, and as database connectivity matures and rendering capabilities improve, real-time 3D GIS mapping will become more common.

The industry should start to see more applications that not only render GIS data in 3D, but interactively morph/update to accurately represent real-time data acquisition.

Couple real-time data with a set of fundamental, yet robust, thematic mapping capabilities and GIS users of tomorrow will be able to making extremely confident decisions in a timely fashion.